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(54) Abstract Title
Measuring device using a toroidal coil

(57) The invention which is the subject of the application is a measuring device known as Rogowski coil which is a toroidal coil which can be connected to measure values of a conductor passing through the aperture defined by the coil. The present invention provides for the forming of a coil using a core of sheet material such as a printed circuit board, on which the coil is formed. The use of sheet material and in particular printed circuit material is that the coil can be formed by applying conducting material and removing portions to leave a series of bands in a coil formation rather than requiring the physical winding of the cold material around a core as is conventionally the case. The core has a central aperture and the coil is configured between the outer edge of the substrate and edge of the aperture. The electrical components required to process the data measured may be mounted on the cove.

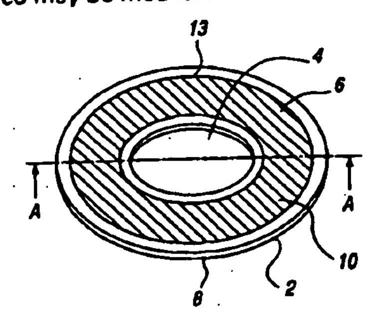

FIG. 1

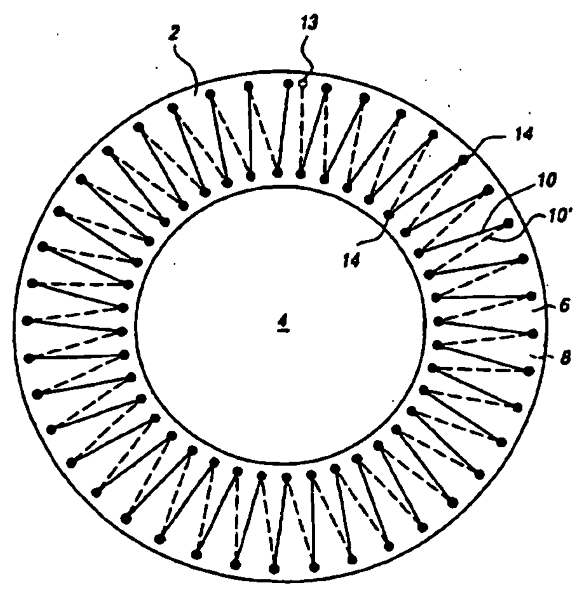

FIG. 3

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

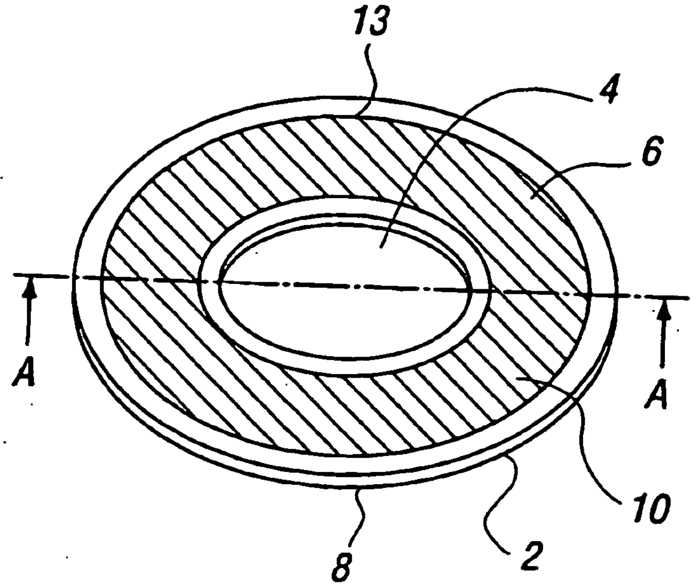

FIG. 1

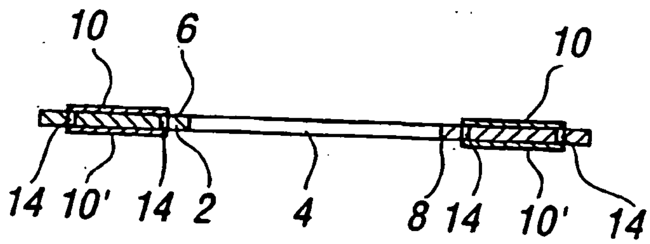

FIG. 2

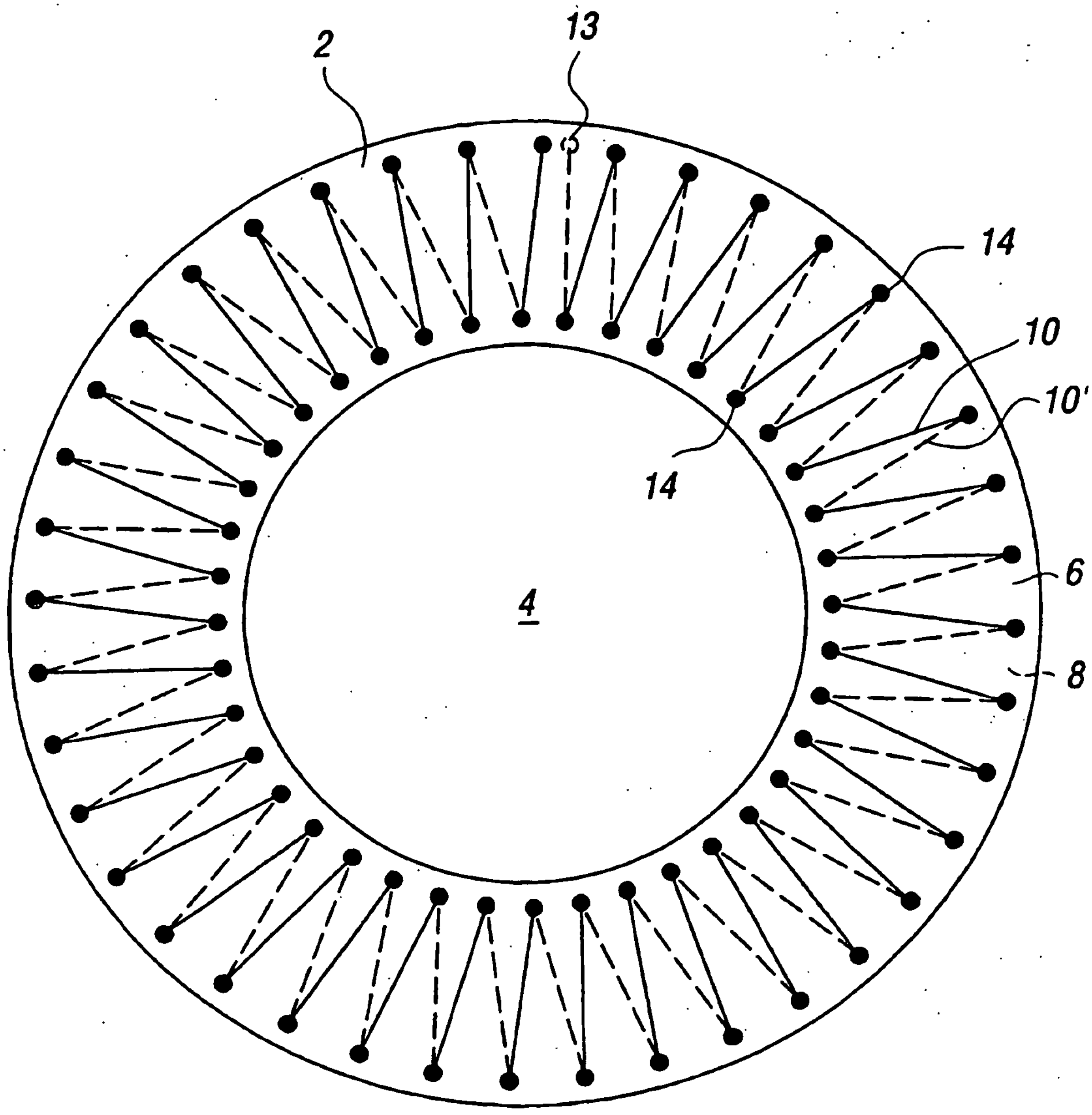

FIG. 3

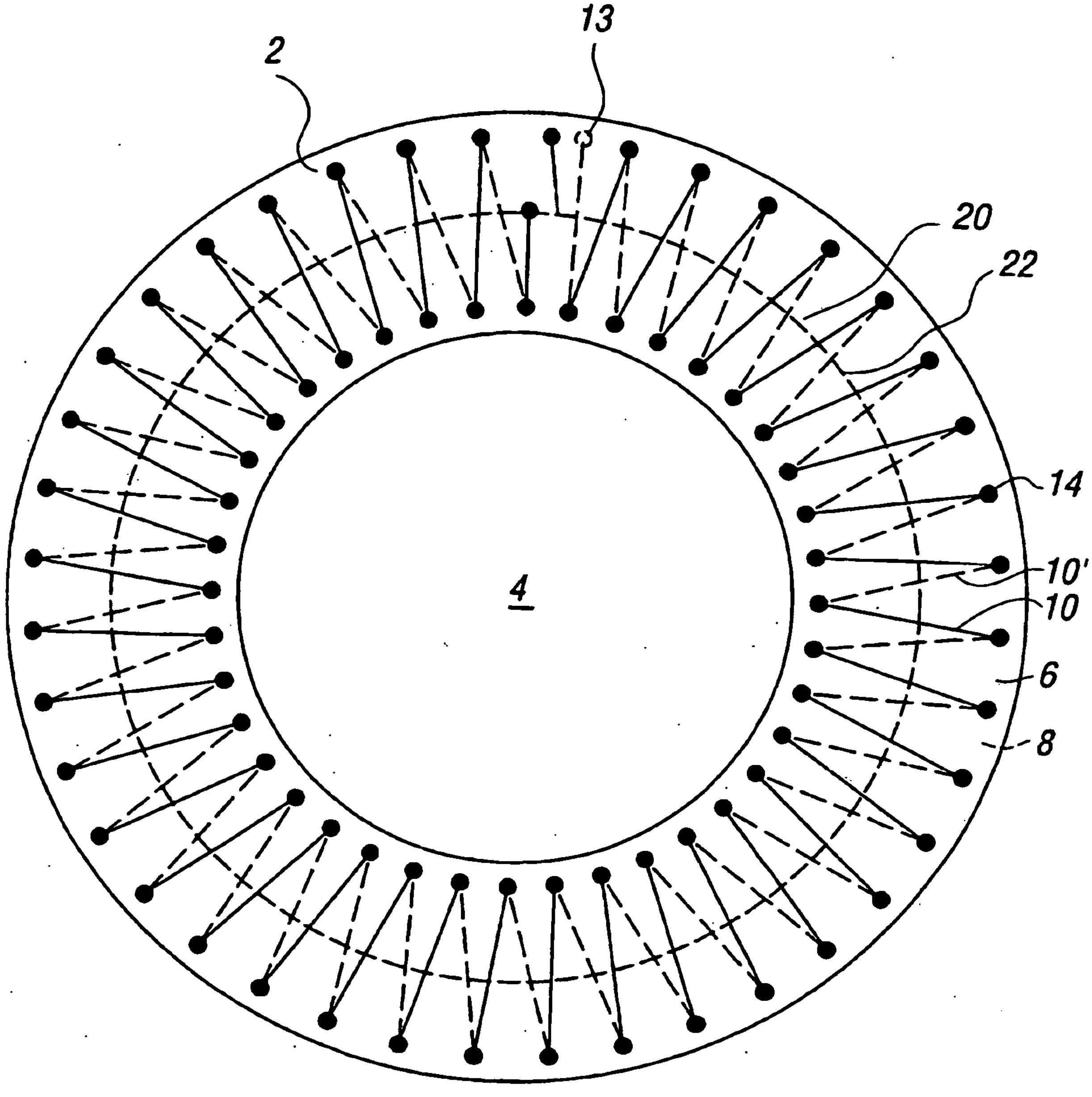

FIG. 4

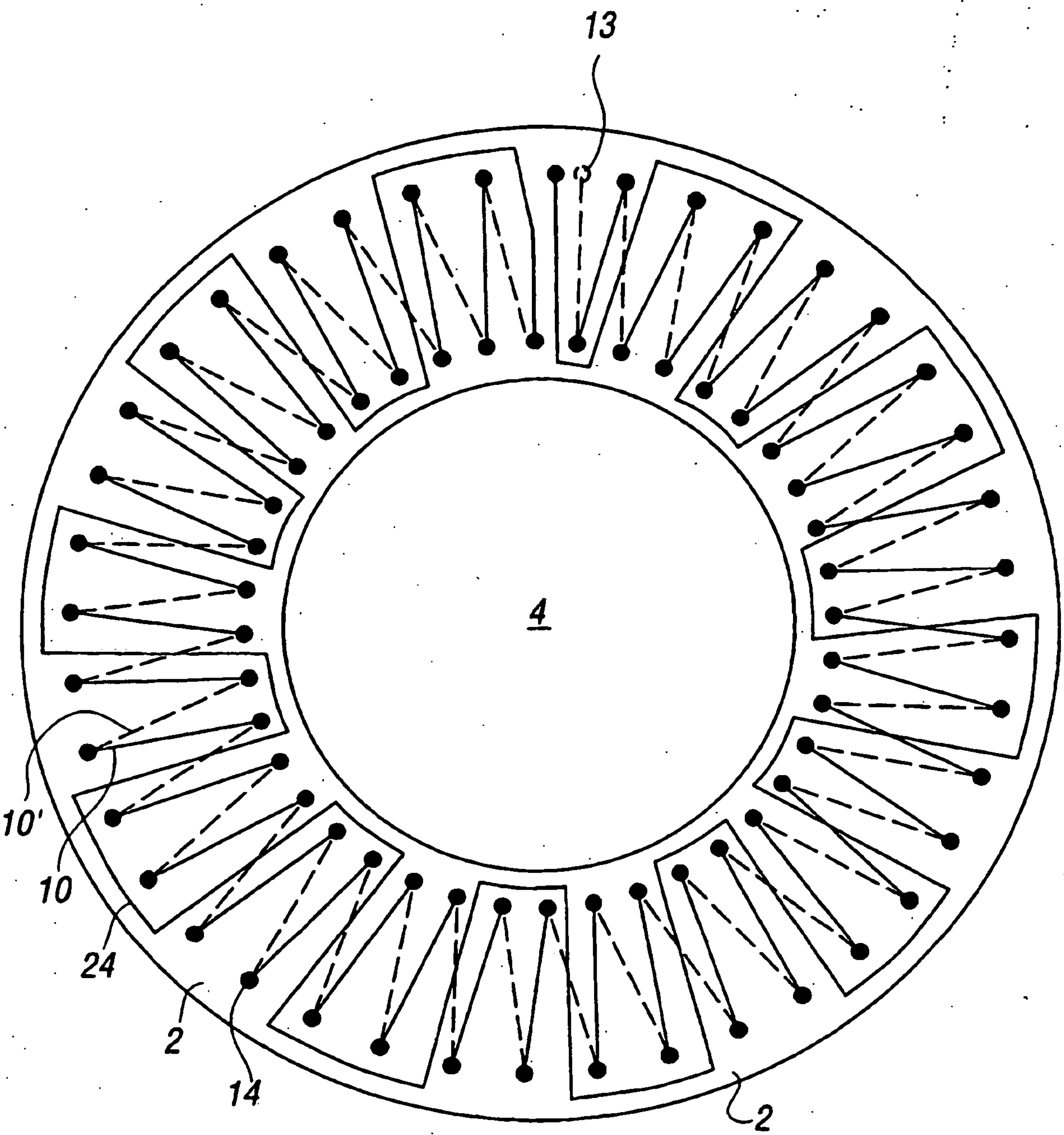

FIG. 5

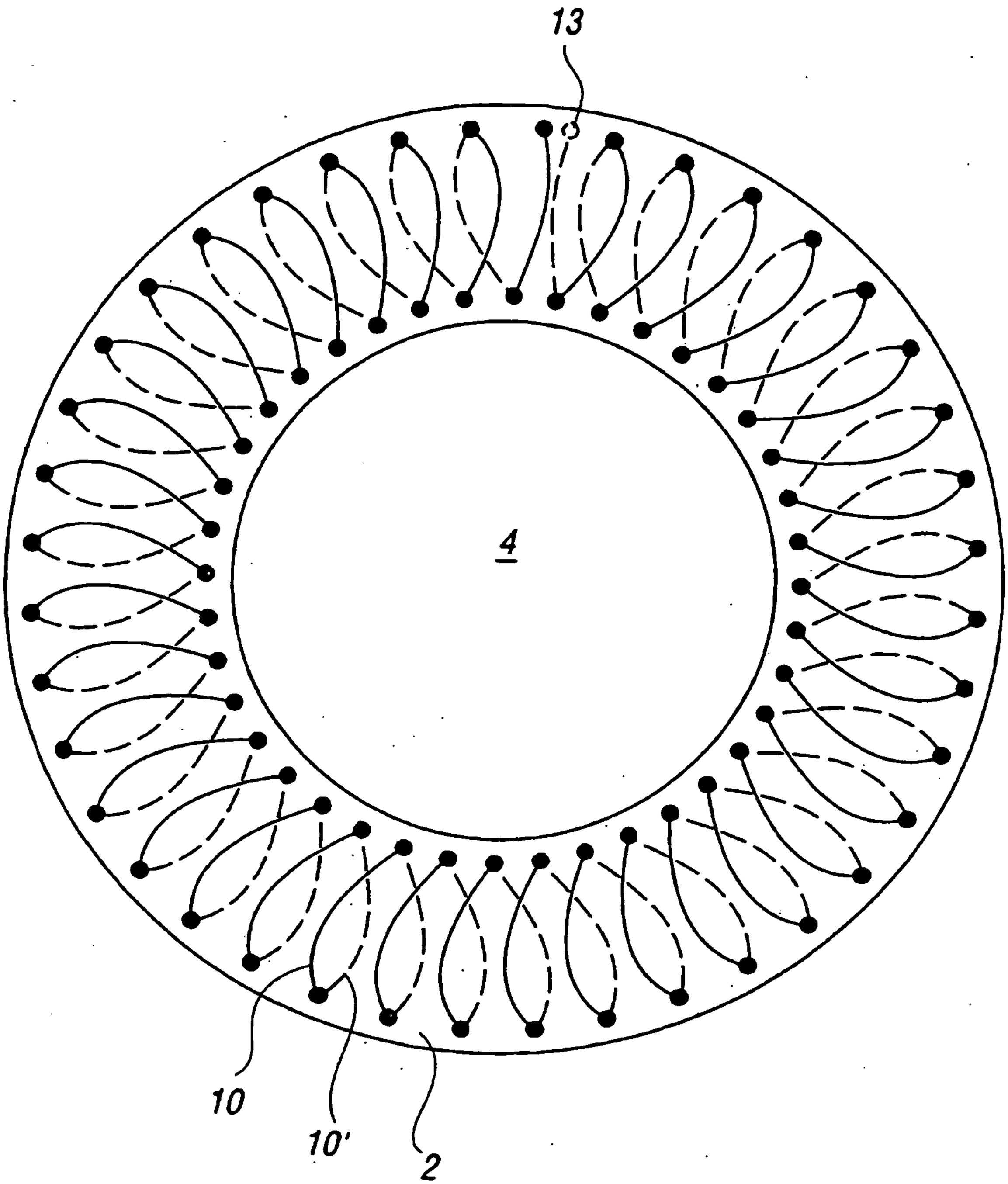

FIG. 6

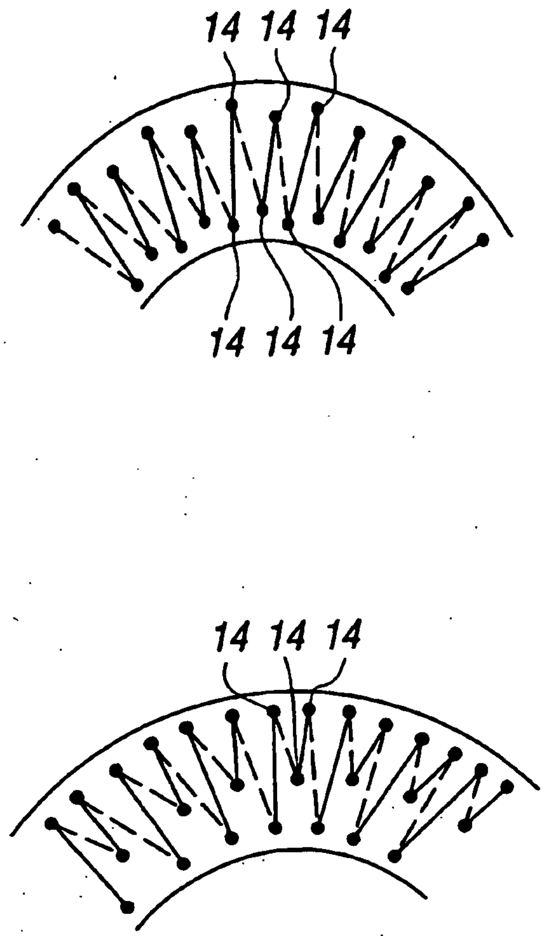

FIG. 7

Measuring Device

The invention to which this application relates is the type of device for use in measuring the alternating current passing along a conductor, and in particular to measuring devices including toroidal coils and known as Rogowski coils.

There are several known methods for measuring alternating current, one of which is using an iron cored current transformer, which is typically large and bulky and therefore inflexible in use, and another method is to use a transducer in the form of a toroidal coil wound, usually on a non-magnetic former which, in order for the measurements to be accurate, requires the device to be carefully manufactured. This type of device is known as a Rogowski coil but is hereinafter referred to as a toroidal coil.

In use the winding of the toroidal coil is used to sense the magnetic field created around a conductor which carries an alternating current. The measurement of the magnetic field can be used to provide a highly accurate measurement of the current without the need for electrical contact to be made with the conductor. The coil acts as a mutual inductance to the conductor being measured and the voltage output is proportional to the rate of change of current. The voltage can be measured directly to provide a measurement of the rate of change of current but in most cases the voltage is integrated in one of several ways to produce an output that reproduces the current waveform and thus can be used to measure currents ranging from the milliampere to several million amperes.

A typical form of toroidal coil comprises a length of conducting material wound and coiled around a core which is typically rigid and annular in shape. In order for the coil to provide the correct results care has to be taken in the winding of the conducting material around the core in a toroidal sense and machines have been developed to provide this function, one being the subject of patent GB2041875. The use of machines of this type allows Rogowski coils of the required quality to be produced but the process is time consuming and, as a result, the toroidal coil can be relatively expensive.

Although the machines for winding the conducting material do allow the increased accuracy of the winding of the material, it is known that the individual coils differ slightly from each other in their output when measuring the same current and which differences are caused by unavoidable manufacturing tolerances. Although there are various ways of compensating for these differences they require additional expense in terms of extra time and care in the construction of the coil or the winding or associated electronic circuits.

The aim of the present invention is to provide a toroidal coil form which can be reproduced time after time and with confidence that any differences between the measurements to be obtained by the respective coils will be insignificant and also to make the coils in a manner which allows the same to be made with cost and time savings.

In a first aspect of the invention there is provided a toroidal coil comprising a core, conducting material in a coil configuration on said core and a connection from the conducting material to allow measurements to be processed, and wherein said core is a substrate onto which the conducting material is applied and formed and/or connected into a coil configuration.

In one embodiment the substrate is a printed circuit board material and the conducting material is applied on first and second surfaces of the same and interconnected via clips at the edges of the same and/or connections passing between said surfaces and formed of or coated with said conducting material.

Typically the substrate core is formed so as to have a central aperture through which the conductor with the alternating current passes to be measured.

In one embodiment the coil is constructed from a number of portions which can be engaged and interconnected to allow the coil of the invention to be formed around the conductor to be measured without the need for disconnecting said conductor.

In a further aspect of the invention there is provided a toroidal coil comprising a substrate core having a central aperture and a conducting material applied to surfaces of the core in a coil configuration and wherein said coil configuration is located within the confines defined by the outer and inner edges of the substrate.

The ability to confine the coil configuration within the edges of the substrate can be achieved by interconnecting the conducting material on first and second surfaces of the substrate by forming apertures through the substrate and between the two surfaces and coating the apertures with conducting material or by using wires or other conductors through the apertures so as to contact with and connect the conducting material on both surfaces and form the coil configuration required.

In one embodiment the toroidal coil according to the invention can be provided with an electrostatic mask by coating said first and second surfaces with a suitable material such as copper but insulated from the conducting material which forms the winding so as to enclose or encapsulate the conducting material and substrate.

The conducting material is typically applied to the substrate in the form of the printed circuit board by a conventional technique.

In a further aspect of the invention there is provided a measuring device, said device comprising a substrate, part of which acts as a core for a toroidal coil and onto surfaces of which are applied a conducting material and formed into a coil configuration to form the toroidal coil and wherein another portion of the substrate material is used to mount components in connection with the toroidal coil so formed to allow processing of the data received from the toroidal coil.

In a further aspect of the invention there is provided a method of forming a toroidal coil comprising the steps of forming a core from a sheet substrate with an aperture and having first and second surfaces, applying a conducting material to the first and second surfaces, removing portions of the conducting material from said first and second surfaces to leave a series of bands of conducting material thereon, connecting respective bands on the first and second surfaces to form a coil configuration of said conducting material and attaching external connection means to the conducting material.

In one embodiment the conducting material may be directly applied to the substrate in the required configuration thereby overcoming the need for any removal of conducting material once applied.

The conducting material bands on each of the first and second surfaces can be connected by forming apertures with conducting material through the substrate and/or by clips of conducting material attached to the edges of the substrate.

Specific embodiments of the invention will now be described with reference to the accompanying drawings; wherein

Figure 1 illustrates a perspective view of one embodiment of the invention;

Figure 2 illustrates a sectional end elevation along line A-A of Figure 1;

Figure 3 illustrates a first embodiment of a coil configuration in schematic fashion;

Figure 4 illustrates a second embodiment of coil configuration;

Figure 5 illustrates a third embodiment of coil configuration;

Figure 6 illustrates a fourth embodiment of coil configuration; and

Figure 7 illustrates a detailed view of the arranging of one coil configuration on the substrate.

Referring firstly to Figures 1 and 2 there are illustrated views of one embodiment of a toroidal coil according to the invention wherein the coil comprises a substrate 2, in this case a printed circuit board, provided with an aperture 4 through which the conductor to be measured passes (not shown). On the substrate first and second planar surfaces 6.8 there is applied a conducting material in the form of bands of said material so that that, when connected, the bands on the first and second surfaces form a coil configuration of conducting material 10. The bands are of fine detail and are represented by the hatched area 10 on the front surface 6 of Figure 1. The bands of conducting material can be applied using conventional printed circuit board techniques. The conducting material bands on the first and second surfaces 6,8 are connected by apertures 14, which are coated with the conducting material 10 or by wires through the apertures and therefore allow connection between

bands on the opposing surfaces to form the coil configuration provided with external connection means 13 and hence the toroidal coil as will be readily understood.

The conducting material can be applied to suit specific coil configurations and the conducting material can therefore be applied in a manner so as to recreate the effect of conventional winding configurations but at the same time ensure that the uniform measuring effect can be recreated for each coil made with the same configuration which could not be previously achieved.

A toroidal coil which is manufactured in the way described or any conventional coil will respond to the circumferential magnetic field caused by a conductor passing through the aperture in the coil. However a problem with the coil configuration is that the coil is also sensitive to magnetic fields which have a component perpendicular to the annulus and which can originate from current carrying conductors which lie externally of but adjacent to the toroidal coil. This effect occurs because the progression of the coil winding around the core effectively forms the core into a large loop which is in the plane of the core and is known as the "single turn"effect.

The Figure 3 illustrates one possible form of coil which can be provided on the substrates according to the invention in one embodiment in which the substrate 2 has applied to the first surface and shown in full lines, conducting material bands 10 and to the second or reverse surface and shown in broken lines, bands of

conducting material 10'. The bands 10, 10' are interconnected via connections 14 in the form of coated apertures, said apertures coated with the conducting material and in connection with the band ends, thereby allowing the connection of the bands on said surfaces 6,8 into a coil configuration according to the invention. This form of coil can provide an adequate measurement of the alternating current but where more accurate measurements are required the single turn effect has to be minimised and figures 4-6 illustrate various possible solutions in schematic form which can be incorporated into the toroidal coil formed according to this invention to minimise the single turn effect..

Figure 4 illustrates one embodiment where a third conducting material layer is positioned between the surfaces 6,8. This third layer 20 carries a reverse turn 22 of conducting material as shown. An alternative variation is to provide a further two layers of conducting material to create a second coil configuration which can be sandwiched between the first coil configuration of conducting material 10, 10'. The second coil configuration would be connected in series with the first coil and the configurations would be set so as to cause the outputs from each coil configuration to reinforce for current measurement purposes and the single turn effects of each of the coil configurations cancel each other out.

Yet further, two coil configurations of the type of Figure 1, can be placed side by side and one has a right handed winding configuration and the other has a left handed winding configuration. The two outputs can be connected in series and the outputs

combined for measurement purposes and again the single turn effect of each of the coil configuration cancel each other out.

In some instances it is not practical to have more than two surfaces with a conducting material applied thereto and so it is necessary to provide a reverse turn coil configuration 24 on the first and second surfaces 6,8 as shown in Figure 5. Figure 5 illustrates the reverse turn 24 form which weaves between the conducting material 10 for the first coil configuration on surface 6. Alternatively, the reverse turn could weave between the surfaces 6 and 8 if required. The path of the reverse turn is chosen so that the projection of its area on the plane of the annulus is as equal as possible to the projection of the first coil configuration on the plane of the annulus.

A further alternative arrangement (not shown) is to provide a wire or strip of conducting material and adhere the same to the substrate and attach it to one end of the coil configuration. The wire could also be passed through apertures in the substrate.

A yet further embodiment is shown in Figure 6 in which again only two surfaces 6 and 8 are available. In this arrangement the bands 10, 10' can be shaped so that their projection on the annulus forms a series of backward loops rather than the zigzag pattern of Figure 3. Each back loop generates a small voltage in the opposite sense to the single turn voltage. The geometry of the bands is calculated so that their combined effect cancels out the single turn effect.

The output of the coils according to the invention in ratio with the thickness of the substrate required to be used can be improved by staggering the position of the aperture connections 14 as is shown in Figure 7. This allows the bands of conducting material to be tightly spaced and thereby maximise the coil windings which can be accommodated on the substrate. The staggering of the position of the apertures can be as required in order to accommodate the bands of conducting material in the available substrate surface area.

Claims

1. A toroidal coil comprising a core, conducting material formed with a coil configuration on said core and a connection from the conducting material to allow measurements to be processed from the coil and, wherein said core is a substantially planar substrate with first and second surfaces onto which the conducting material is applied and formed and/or connected into a coil configuration.

2. A toroidal coil in accordance with claim 1 wherein the substrate is a printed circuit board base and the conducting material is applied on first and second surfaces of same.

3. A toroidal coil according to claim 1 wherein the conducting material on the first and second surfaces is interconnected via a series of clips at the edges of the substrate which contacts conducting material on the first and second surfaces.

4. A toroidal coil according to claim 1 wherein the conducting material on the first and second surfaces is interconnected by apertures passing between the said surfaces and formed of or coated with said conducting material.

5. A toroidal coil according to claim 1 wherein the substrate core is formed with an aperture through which a conductor which is to be measured passes to be measured.

6. A toroidal coil according to claim 1 wherein the coil is constructed from a number of portions which are engageable to allow the coil of the invention to be formed around a conductor to be measured.

7. A toroidal coil comprising a substrate core having a central aperture and a conducting material applied to first and second surfaces of the core in a coil configuration and wherein said coil configuration is located within the confines defined by the outer edge of the substrate and the edge of the aperture.

8. A toroidal coil according to claim 7 wherein conducting material is applied to first and second surfaces of the substrate and a series of apertures are formed between the first and second surfaces and said apertures are coated with conducting material to connect with the conducting material on the first and second surfaces to form the coil configuration.

9. A toroidal coil according to claim 7 wherein conducting material is applied to first and second surfaces of the substrate and apertures are formed through the substrate between the first and second surfaces and the said conducting material on the first and second surfaces is connected by using wires or other conductors which pass through the apertures.

10. A toroidal coil according to any of the preceding claims wherein the coil is provided with an electrostatic mask by coating said first and second surfaces with a suitable material which is

insulated from the conducting material of the coil so as to enclose or encapsulate the conducting material and substrate.

11. A measuring device, said device comprising a substrate, at least part of which acts as a core and onto the surfaces of which are applied conducting material and formed into a coil configuration to place around a conductor to be measured and wherein another portion of the substrate material is used to mount components in connection with the coil so formed to allow processing of the data received from the coil during the measuring operation.

12. A method of forming a toroidal coil comprising the steps of forming a core from a sheet substrate, forming an aperture in the core and on first and second surfaces of the substrate, applying a conducting material, removing portions of the conducting material from said first and second surfaces to leave a series of bands of conductive material thereon, connecting respective bands on the first and second surfaces to form the same into a coil configuration of said conducting material.

13. A method according to claim 12 wherein external connection means are attached to the conducting material to allow readings to be obtained therefrom.

14. A method according to claim 12 wherein the conducing material is applied to the surfaces in a band configuration without the need to remove any further material thereafter.

15. A method according to claim 12 wherein the conducting material bands on each of the first and second surfaces are connected by forming apertures with conducting material through the substrate and/or by clips of conducting material attached to the edges of the substrate.

16. A toroidal coil as hereinbefore described with reference to the accompanying drawings.

17. A method of forming a toroidal coil as hereinbefore described with reference to the accompanying drawings.

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Application No:	GB 9921393.6	**Examiner:**	Rosie Hardy
Claims searched:	1 to 6	**Date of search:**	10 February 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): H1T (TBB TAA)

Int Cl (Ed.7): G01R 15/18 H01F 5/00 17/00 27/28 38/28

Other: ONLINE: EPODOC JAPIO WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	EP0893699 A1 TOKIN CORPORATION See figures 7 to 9	1 & 12 at least
X	EP0856855 A1 MITSUBISHI See figures 10, 15 to 18	1, 11 & 12 at least
X	EP0587491 A1 GEC ALSTHOM See english language abstract	1, 4, 11 & 12 at least
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